



Infrared Reflectance Imaging for Environmentally Friendly Corrosion Inspection Through Organic Coatings

Project Number WP-0407

Authors:

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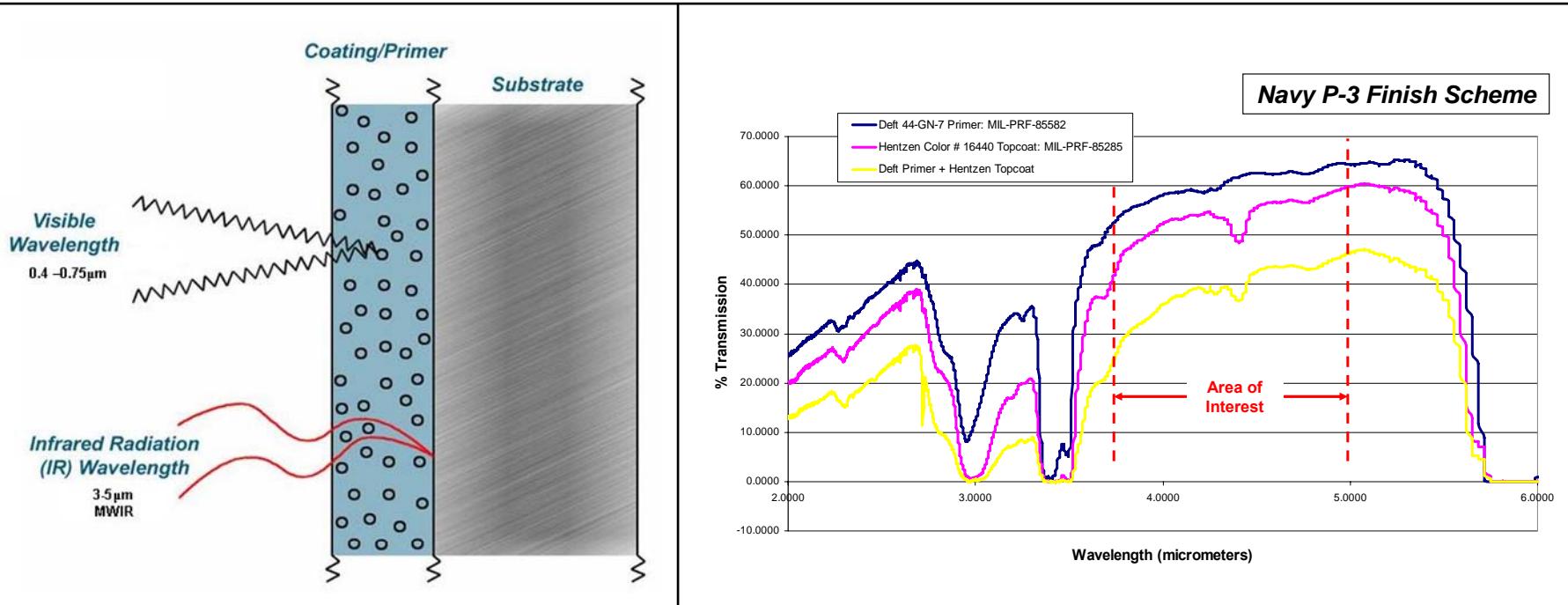
ESTCP Conference
Tempe, AZ

25-29 February 2008



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Background



Note: Typical military specification coating systems are transparent in the 3-5 micrometer wavelength.

U.S. Patent: 7,193,215

U.S. Patent: 7,164,146



Technical Objectives

- Demonstrate Infrared Reflectance Imaging Technique (IRRIT) as an enhanced inspection tool when compared to visual inspection.
- Establish and prove the technique and determine cost/waste reductions from actual maintenance operations.
- Reduce environmental impacts
 - HAZMATs
 - VOCs
 - Chromates
 - Inorganic HAPs
- Reduce costs to inspect and repair coatings by minimizing labor hours and flow/down times.



Technical Approach

NAVAIR Jacksonville, FL

P-3 OML Dem/Val



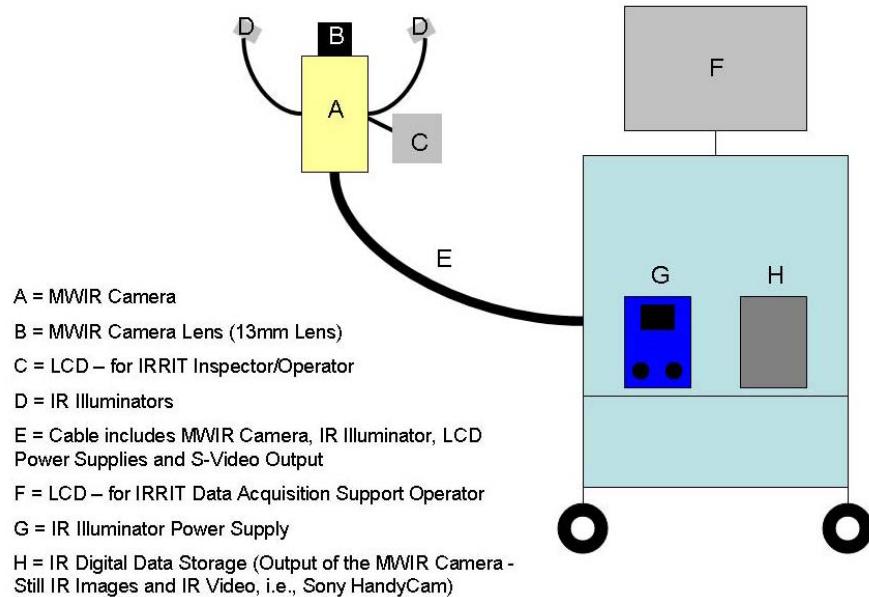
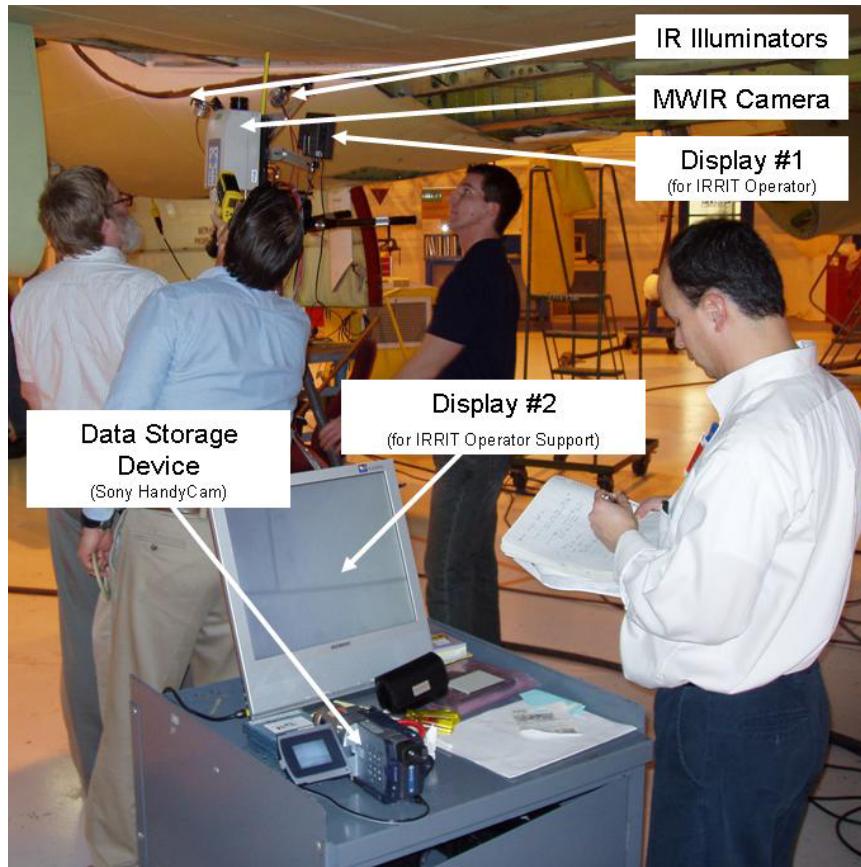
Oklahoma City ALC, OK

KC-135 and B-52 IML Dem/Val



Technical Approach

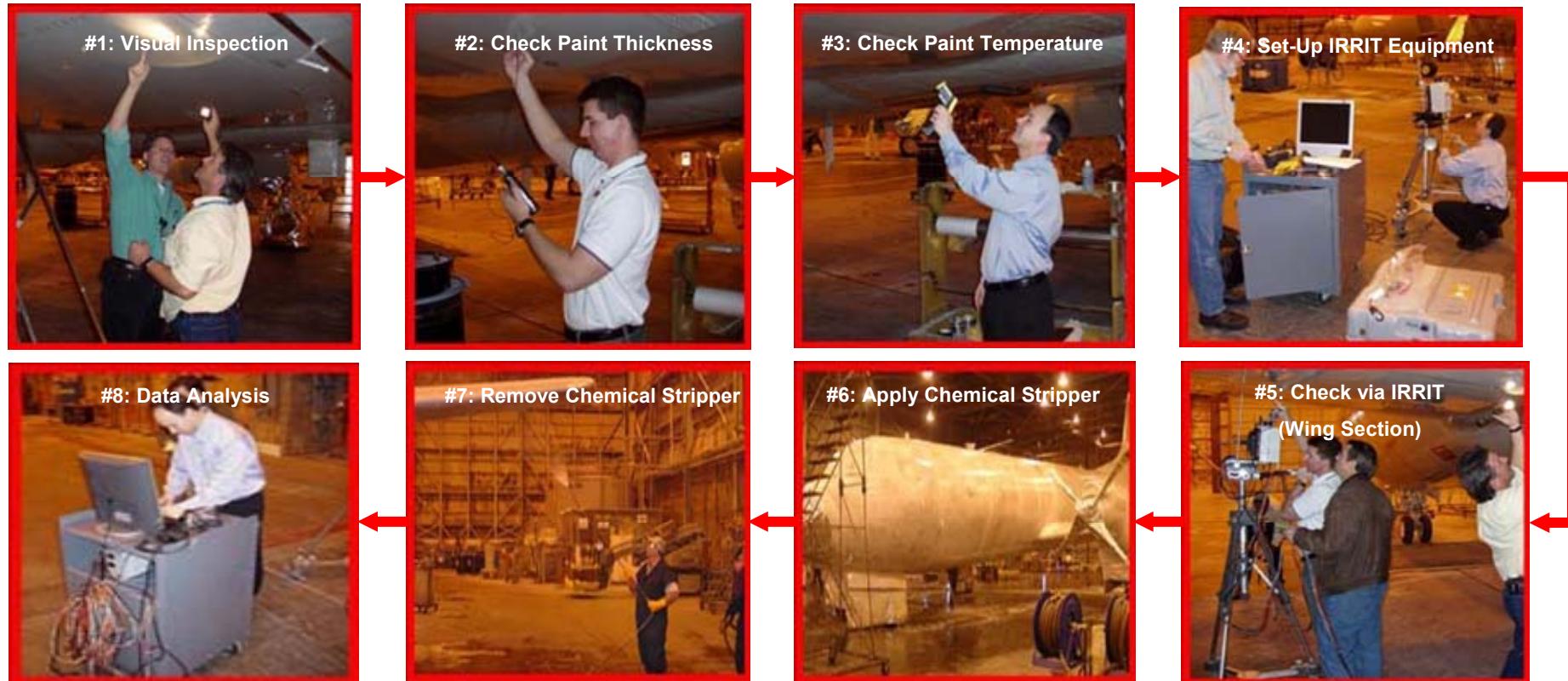
IRRIT System Components





Technical Approach

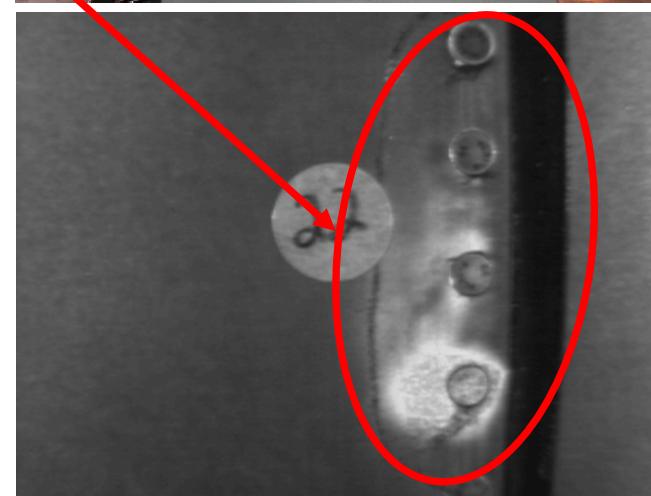
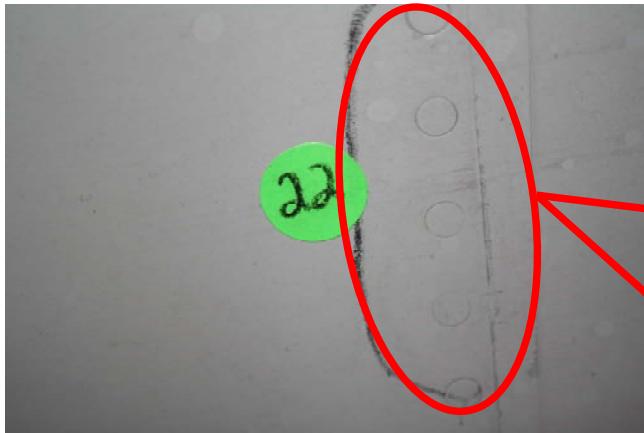
Dem/Val Process



- Consolidate and Review all data
- Statistical analysis of the number of corrosion sites identified
- Compare Visual versus IRRIT results for accuracy

Technical Approach

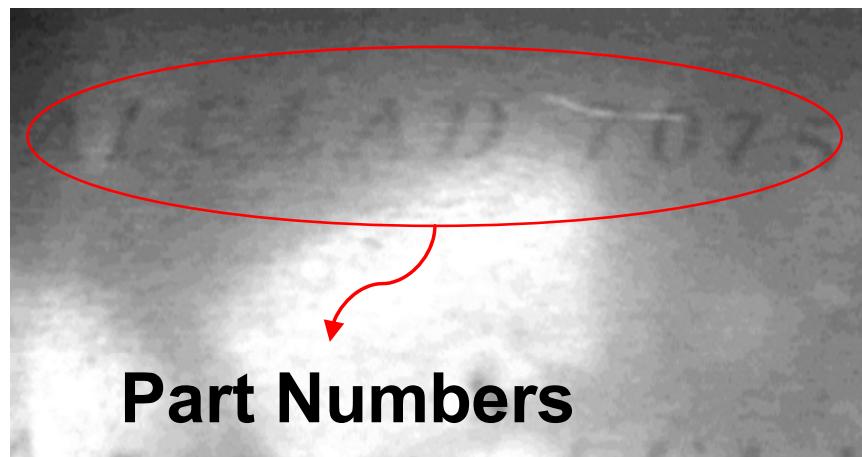
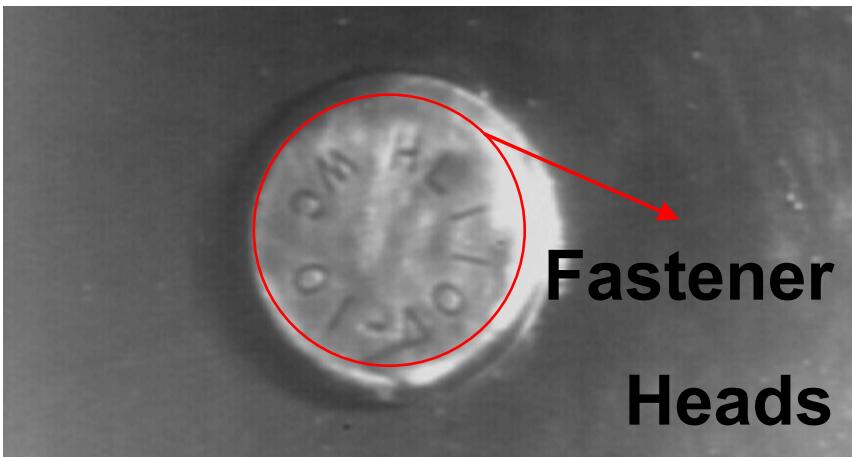
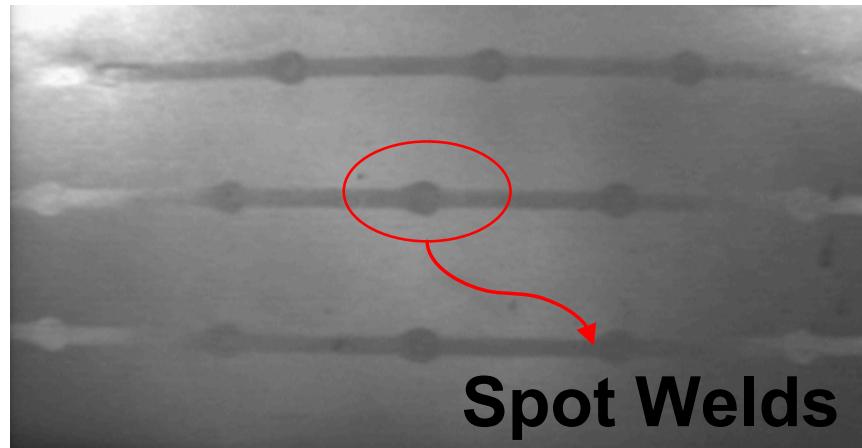
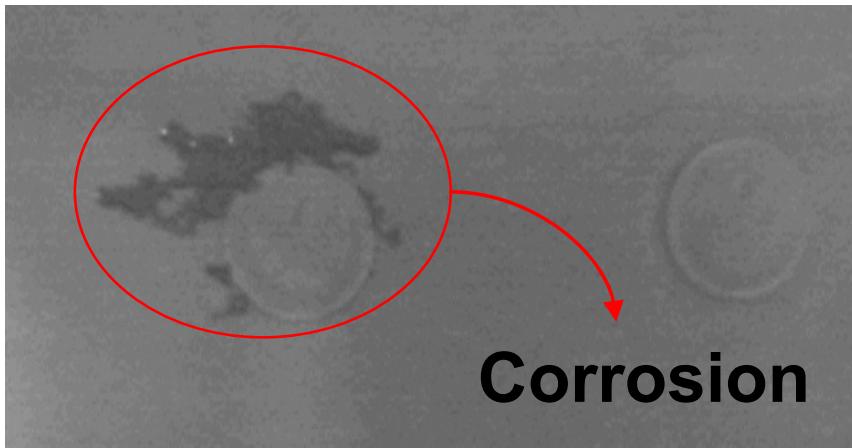
IRRIT System During Dem/Val





Additional IRRIT Information

By the way....



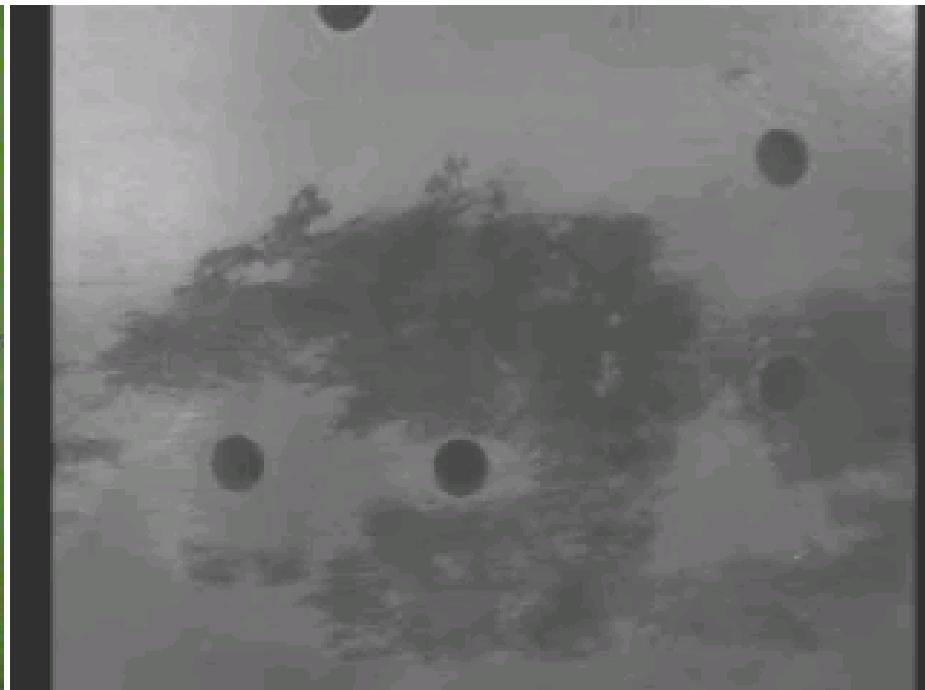


VISUAL AND IRRIT VIDEO

Visual Video



IRRIT Video

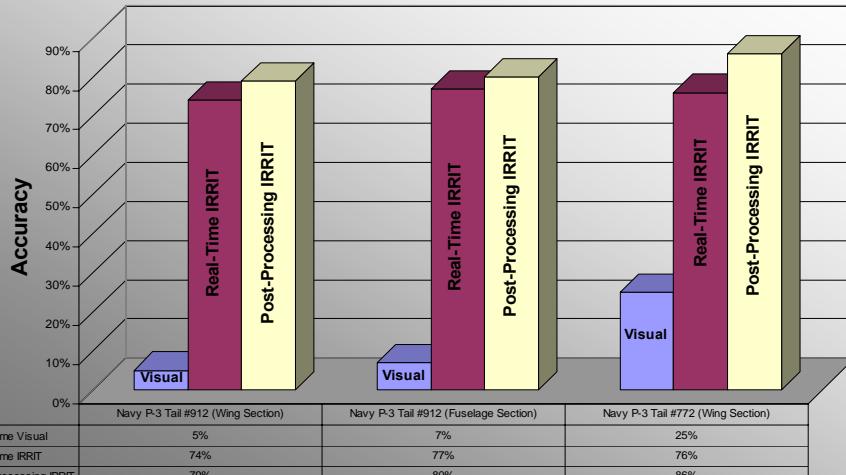




Results - IRRIT Dem/Val Data

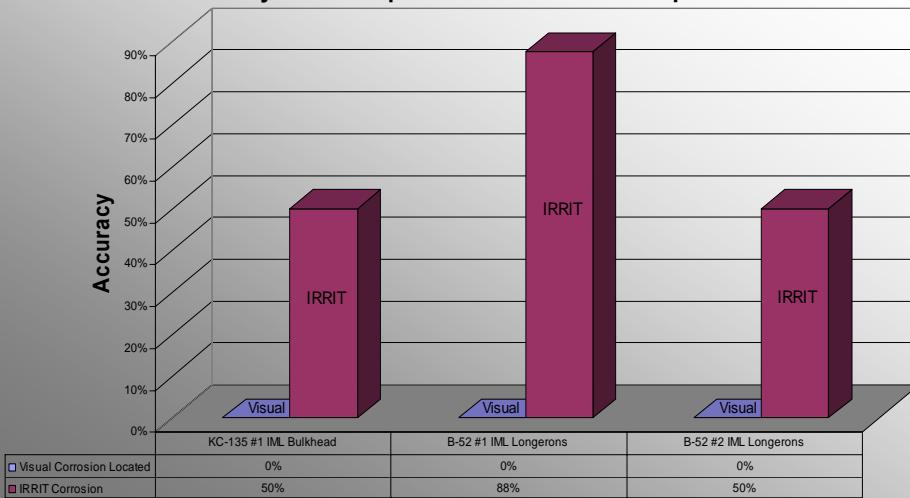
Navy P-3 OML

Accuracy: IRRIT Inspection versus Visual Inspection



USAF KC-135 and B-52 IML

Accuracy: IRRIT Inspection versus Visual Inspection



Navy P-3 OML Dem/Val Results

IRRIT Inspection Accuracy (Post-Processing)
79%, 80%, 86%

Visual Inspection Accuracy (Real-Time)
5%, 7%, 25%

USAF KC-135 and B-52 IML Results

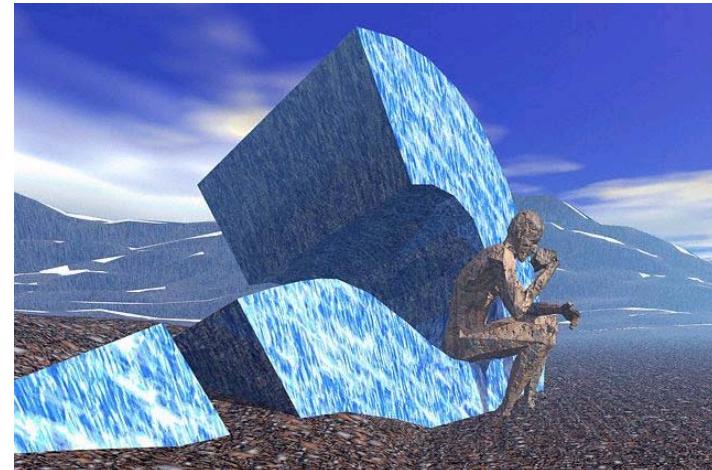
IRRIT Inspection Accuracy (Real-Time*)
50%, 88%, 50%

Visual Inspection Accuracy (Real-Time)
0% - No Corrosion Located Visually

*Post-Processing not performed for OC-ALC IML Dem/Val due to localized stripping.

Results

Why?



1. The IR method directly images corrosion by-product through the paint system due to reflectance contrast differences of the substrate.
2. The visual method relies upon the identification of paint surface irregularities/blistering (i.e., paint degradation) as a result of substrate volume changes associated with corrosion formation.



Transition Plan

- IRRIT demonstrations and briefings occurred at multiple DoD facilities. Resulting in additional endorsements beyond the scope of the planned Dem/Val, which include:
 - USN P-3, E-6, T-45, NAVAIR Materials
 - USCG NDI Program
 - USAF Pending
- Technology Users:
 - Inspectors, quality assurance specialists, and engineers within applicable maintenance and engineering departments of the DoD.
 - Engineering Tool – RCM, E.I., Failure Analysis.
 - E&E/NDI – Conditional Based Maintenance.
 - Quality Assurance – Corrosion control program assessments.





Transition Plan

- Acquiring IRRIT System:
 - IRRIT system procurement may be performed as individual component purchases (MWIR camera) later integrated by the user community or through IRRIT System Kits produced and provided by Northrop Grumman Technical Services (Bethpage, NY).
 - MWIR Camera
 - IR Bandpass Filter
 - Data Capture/Storage System
- IRRIT System Operating Training
 - Infrared Training Center (ITC) Certification Level 1, 2, and 3
 - Currently certified trained IR Inspectors for EA-6B, NDI, Corrosion, and NATEC technicians.
 - Written practice
 - Site specific task training (IQR)
 - Northrop Grumman Technical Services (Bethpage, NY), to include, operating instructions and support for the IRRIT MWIR camera plus all required accessories.



Transition Plan

NAVAIR Materials Endorsement Letter

11 April 2007

FROM: Materials Engineering Division (AIR-4.3.4)
TO: NAVAIR JAX 4.9.7.6; John E. Benfer (WP-0407 Principle Investigator)

SUBJ: INFRARED (IR) REFLECTANCE IMAGING THROUGH AIRCRAFT PAINT SYSTEMS

1. AIR-4.3.4 has reviewed technical information and witnessed field demonstrations associated with infrared reflectance imaging of corrosion through aircraft paint systems. This technology has demonstrated capability to detect and image surface corrosion in an industrial environment while utilizing a commercially available off-the-shelf (COTS) mid-IR camera.
2. Scheduled maintenance processes that involve stripping paint from aircraft surfaces or disassembling components for corrosion inspection can be reduced or eliminated using this technology by providing enhanced inspection capability in support of ground support equipment (GSE), weapons, avionics and component product lines. The availability of a quick, reliable, and simple nondestructive technique that can detect and characterize corrosion hidden under aircraft coating systems, would reduce inspection times and costs, and reduce hazardous waste generation from paint and depaint operations.
3. This technology is also capable of providing enhanced inspection data and documentation associated with corrosion-related failure analyses, engineering investigations, and research, development, testing, and evaluation (RDT&E) programs. Continued research in this area could lead to the development of a system that significantly improves the corrosion inspection process and thereby reduces the risk of failure in aircraft structural component and ultimately improve flight safety. All new and legacy platforms can benefit from this technology; therefore, AIR-4.3.4 recommends both the continued investment into this technology, as well as, the immediate application where applicable.
4. Please contact me if further information is required. I can be reached at (904) 542-4521 x101 or by e-mail at john.yadon@navy.mil.

John L. Yadon
Materials Engineering (AIR-4.3.4)

Draft Technical Manual

MID WAVE INFRARED INSPECTION OF CORROSION UNDER PAINTED AIRCRAFT COMPONENTS

GENERAL THEORY AND INSTRUCTIONS

Reference Material

| | |
|---|---------------------------|
| Aircraft Weapons System Cleaning and Corrosion Control..... | NAVAIR 01-1A-509 |
| Infrared Training Center..... | ITC Level I Course Manual |
| FLIR Systems MilCAM RECON Operators Manual | 17485-000 Rev C |

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Transition Plan

- E-6 Technology Implementation
 - As a result of successful OC-ALC Dem/Val on USAF KC-135 and B-52, the E-6 engineering office is currently planning IRRIT inspections.
 - Conditional assessment of aircraft repaint
 - Maintenance induced damage
 - Rapid inspection or surface cracks (additional program R&D may be required, program related funding)



Navy E-6 → Boeing derived the E-6A from its commercial 707 to replace the aging EC-130Q

Unit Cost: \$141.7 million

Length: 150 feet, 4 inches (45.8 meters)

Wingspan: 148 feet, 4 inches (45.2 meters)

Height: 42 feet 5 inches (12.9 meters)

Weight: Max gross, take-off. 342,000 lbs
(154,400 kg)



Transition Plan

- Future IR cameras will be smaller, lighter and more portable. These improved cameras will increase inspection rates, enhance ergonomics, and the capability for inspection of more complex geometries.
- October 2007 IR Thermography Conference – Community will be IR thermography end users and developers for technology improvement purposes.





Cost Benefit Summary

- Cost of strip and repaint for OML of a single P-3 aircraft: \$129,565
- Cost of single IRRIT Merlin camera system: \$87,600*

*10% annual maintenance cost;
\$17,000 training cost

**Based off partially burdened
\$65/hour labor rate.

| Category | Baseline (per aircraft) |
|--|----------------------------|
| Labor** | \$85,397 |
| Materials | \$21,233 |
| Utilities | \$144 |
| HAZMAT Disposal | \$22,791 |
| TOTAL | \$129,565 |
| VOC Release | 3,423 lbs |
| Total chromates applied | 24 lbs |
| Total hazardous waste generated | 11,273 lbs |



Cost Benefit Summary

- Implementation Scenarios
 - Condition-based Maintenance – Treat aircraft according to pre-induction inspection performed using IRRIT (requires two IRRIT camera systems).
 - Interval Shift – Programmatic change of paint interval resulting from increased confidence from enhanced corrosion inspection data.

“Engineers are inherently conservative with disposition requirements with insufficient data” – 707 Users Conference.

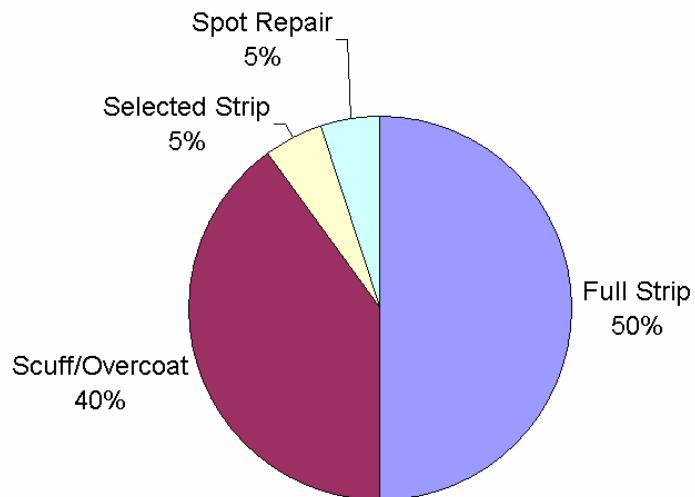


Cost Benefit Summary

Condition-based Maintenance; 25 aircraft /year

| Category | Quantity |
|---------------------------|--------------------|
| Capital Costs | |
| Equipment Cost | \$175,200 |
| Training Cost | \$17,080 |
| Total Capital Cost | \$192,290 |
| Annual Costs | |
| Full Strip (50%) | \$1,645,971 |
| Scuff/Overcoat (40%) | \$719,331 |
| Selected Strip (5%) | \$112,913 |
| Spot Repair (5%) | \$23,087 |
| IRRIT Maintenance | \$17,520 |
| Total Annual Costs | \$2,518,822 |

| Simple Payback Period | |
|--|------------------|
| Baseline (per year) | \$3,239,128 |
| Condition-based | \$2,518,822 |
| Annual Savings | \$720,306 |
| Simple Payback on Capital Cost (\$192,290) | 0.27 years |
| Hazardous Waste Savings | 96,502 lbs |
| VOC Savings | 38,431 lbs |



Note: %'s derived from H-53 legacy data.



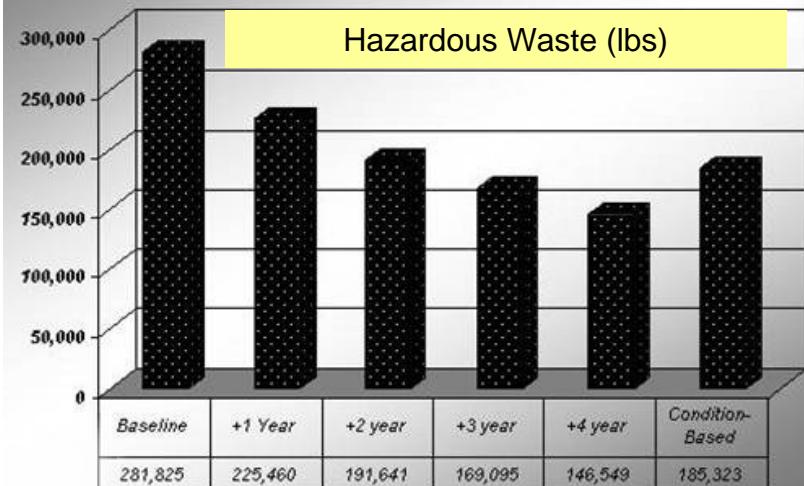
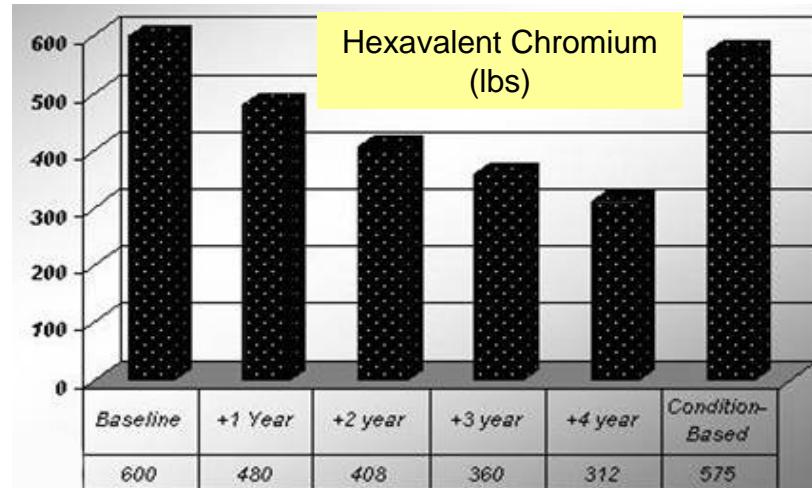
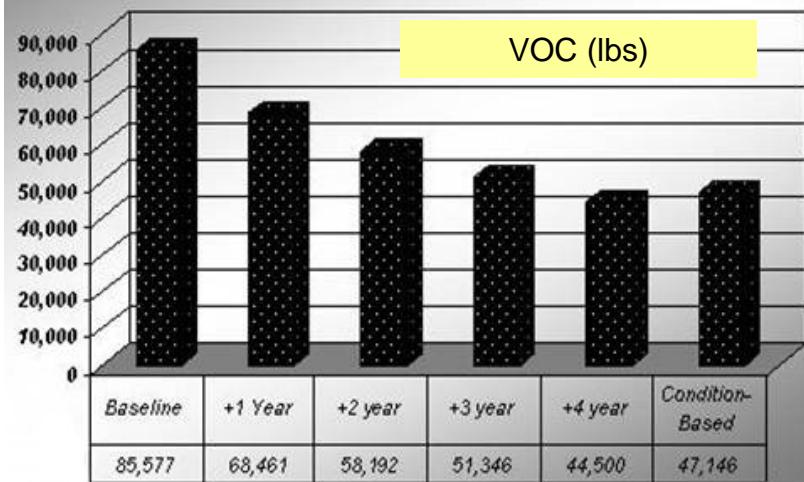
Cost Benefit Summary

Maintenance Cycle Extension

| Yearly aircraft | Baseline: 25 | +1 Year: 20 | +2 Year: 17 | +3 Year: 15 | +4 Year: 13 |
|-----------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Capital Costs | | | | | |
| Equipment | \$0 | \$87,600 | \$87,600 | \$87,600 | \$87,600 |
| Training | \$0 | \$17,080 | \$17,080 | \$17,080 | \$17,080 |
| Annual O&M Costs | | | | | |
| Labor/Equip. | \$2,134,925 | \$1,716,700 | \$1,460,509 | \$1,289,715 | \$1,118,921 |
| Materials | \$530,829 | \$424,663 | \$360,964 | \$318,498 | \$276,031 |
| Utilities | \$3,600 | \$2,880 | \$2,448 | \$2,160 | \$1,872 |
| EHS | \$569,774 | \$455,819 | \$387,446 | \$341,865 | \$296,283 |
| TOTAL | \$3,239,128 | \$2,600,063 | \$2,211,367 | \$1,952,237 | \$1,693,107 |
| Annual Savings | N/A | \$639,066 | \$1,027,761 | \$1,286,891 | \$1,546,022 |
| Simple Payback | N/A | 0.16 years | 0.10 years | 0.08 years | 0.07 years |
| Hazardous Waste Savings | N/A | 56,365 lbs | 90,184 lbs | 112,730 lbs | 135,276 lbs |
| VOC Savings | N/A | 17,116 lbs | 27,385 lbs | 34,231 lbs | 41,077 lbs |



Cost Benefit Summary

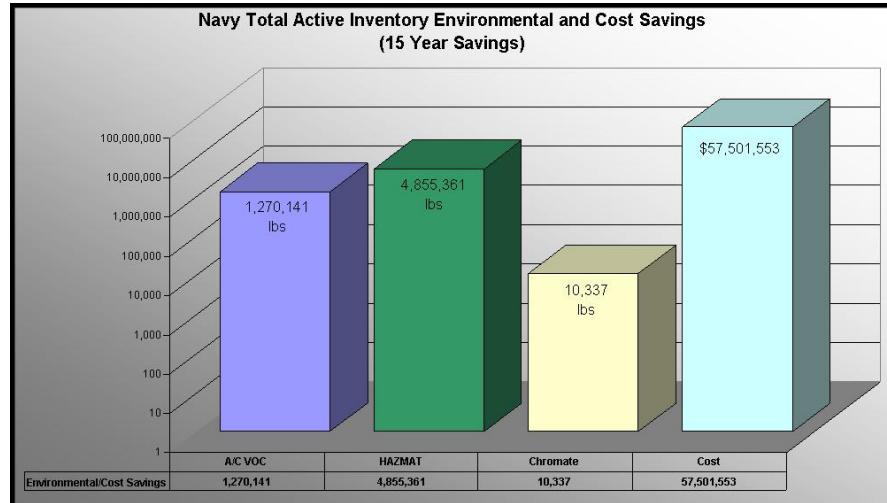


P-3 pollution prevention reductions associated with IRRIT implementation for condition based maintenance and paint interval extension.

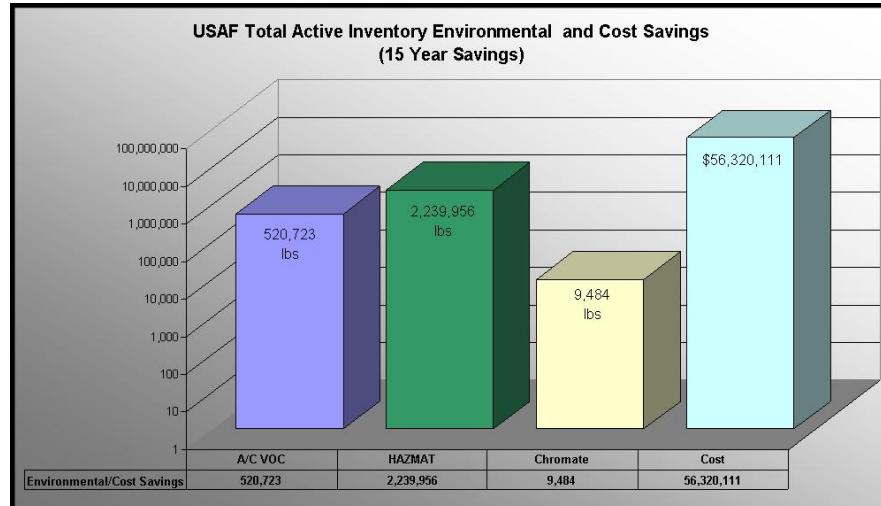


Estimated P2 Savings

Navy OML and IML



USAF OML and IML



Estimated 15 Year Savings (Navy and USAF Combined)

| A/C VOC | Hazardous Waste | Chromate | Cost |
|----------------------|----------------------|-------------------|----------------------|
| 1,800,000 lbs | 7,100,000 lbs | 20,000 lbs | \$114,000,000 |

Note: The above values project savings associated with full implementation of IRRIT on all applicable Navy and USAF programs.

Based on 3 year OML stripping interval shift and avoiding 100 sqft chemical stripping of IML.



Conclusions and Summary

- The IRRIT was validated as an enhanced corrosion inspection tool and consistently demonstrated greater accuracy than existing visual inspection techniques.
 - Significant pollution prevention savings can be realized for programs that implement the IRRIT technology.
-

- IRRIT inherently produces a data record to supplement engineering disposition.
- The inspection rate of the IRRIT was approximately half the rate of visual inspection. However, improved inspection rates are expected with new generation camera systems.



Publications

- Strategic Environmental Research & Development Program (SERDP). *Final Report, “Non-Destructive Testing of Corrosion Under Coatings”*, Project Number 1137, Dated 1 September 2004.
- United States Patent 7,164,146 - System for Detecting Structural Defects and Features utilizing Blackbody Self-Illumination
- United States Patent 7,193,215 - System and Method for Imaging of Coated Substrates
- United States Patent Application 20060289766 - Spectral Filter System for Infrared Imaging of Substrates Through Coatings
- United States Patent Application – IRRIT Enhanced Imaging
- J. Steve Cargill et al., “Nondestructive Testing for Corrosion under Paint” *Materials Evaluation*, monthly periodical of American Society for Nondestructive Testing, February 2005
- Briefing, NAVAIR AUAV Engineering Conference (May 2006)



Conclusions and Summary

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Project Number WP-0407**

Mr. John Weir
Northrop Grumman Corporation

ESTCP Conference
Tempe, AZ

24-29 February 2008

NAV AIR NORTHROP GRUMMAN CTC

QUESTIONS

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Integrated Systems Eastern Region
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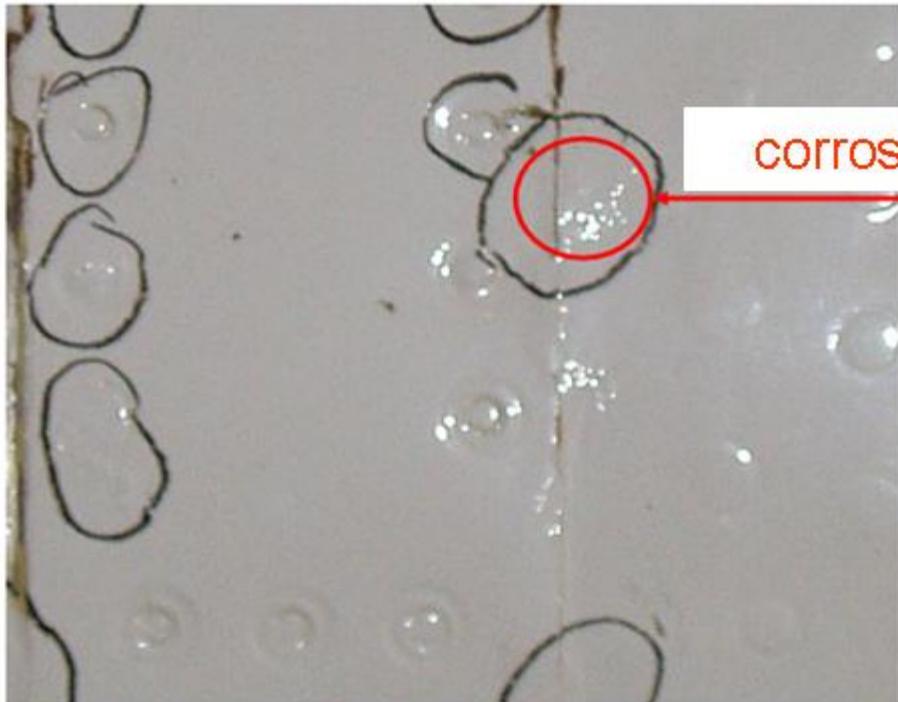
Additional contributors to this project were: Mr. Brian Pollock (WP-AFB project manager), Mr. Matthew Campbell (CTC project manager), Mr. John Benfer (NAVAIR Jacksonville, principal investigator), Mr. Steven Chu (NGC), Mr. Nils Fonneland (NGC), Mr. Dennis Leyble (NGC), Mr. Mike Miller (CTC), Mr. David Allen (ASM Management), and Mr. John Speers (WP-AFB).



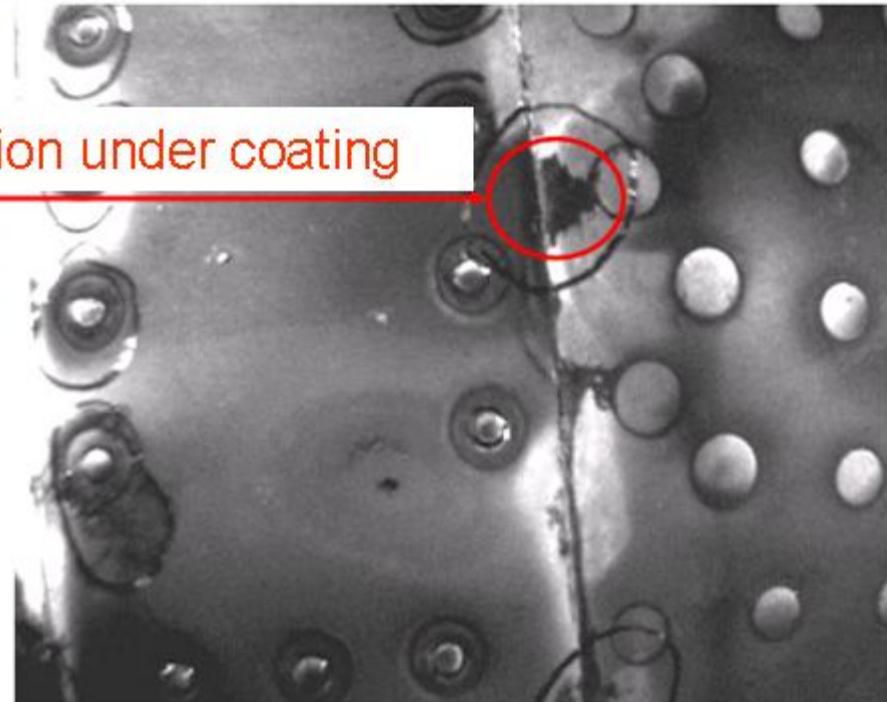
Back-Up

IRRIT Examples

Visual Image



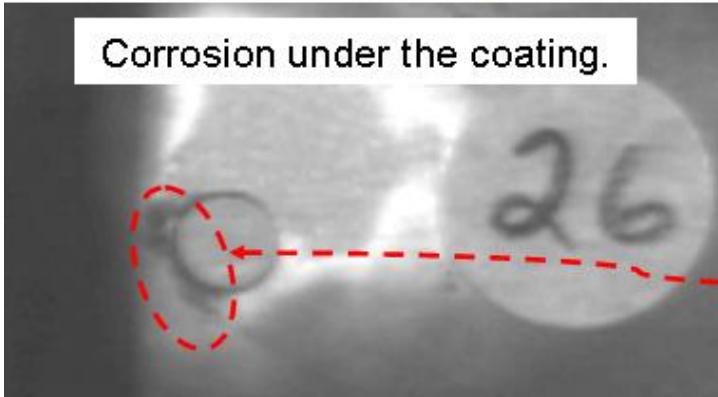
IR Image



IRRIT Examples

IR Painted Image

Corrosion under the coating.



Visual Stripped Image

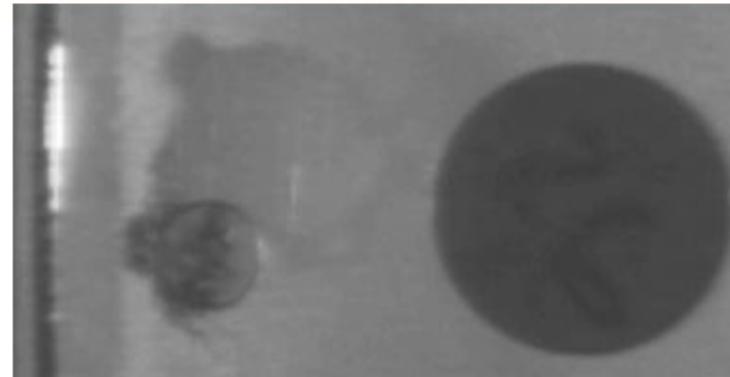
Corrosion confirmed via chemical stripping coating.



Visual Painted Image



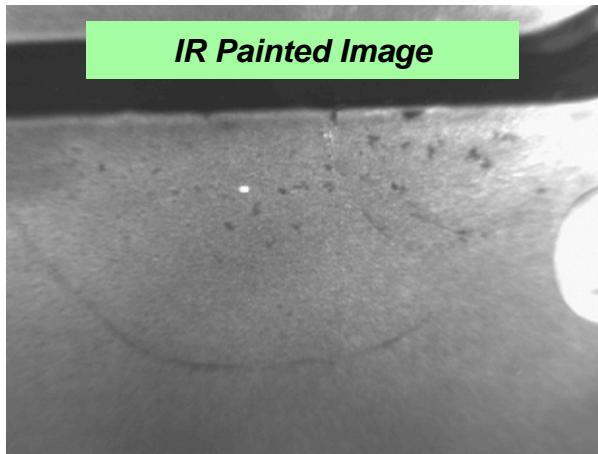
IR Stripped Image



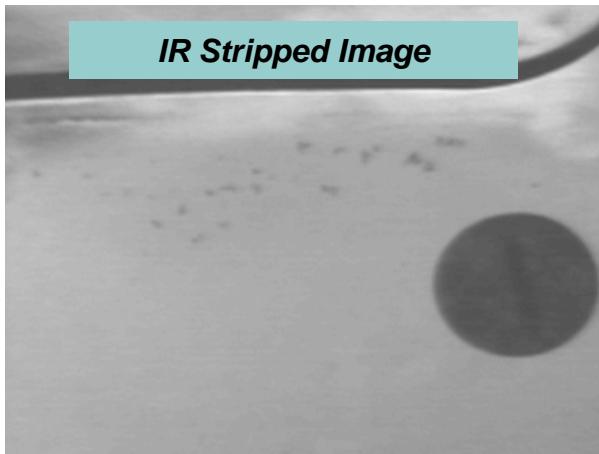


IRRIT Examples

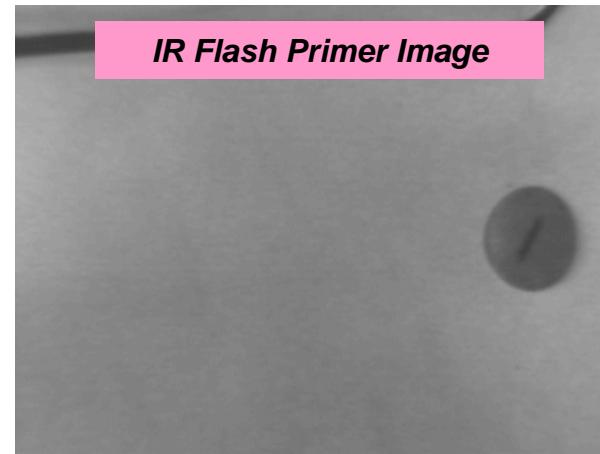
IR Painted Image



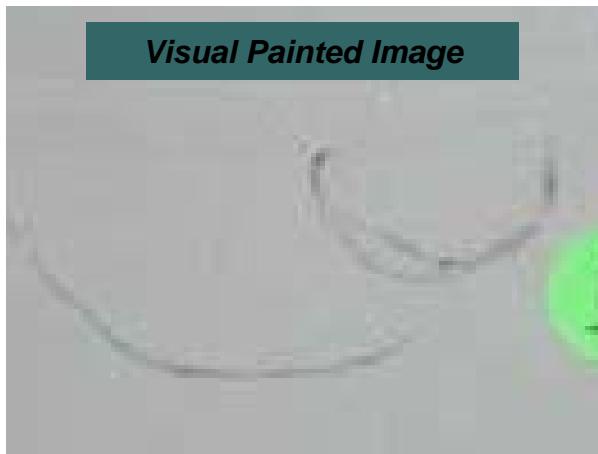
IR Stripped Image



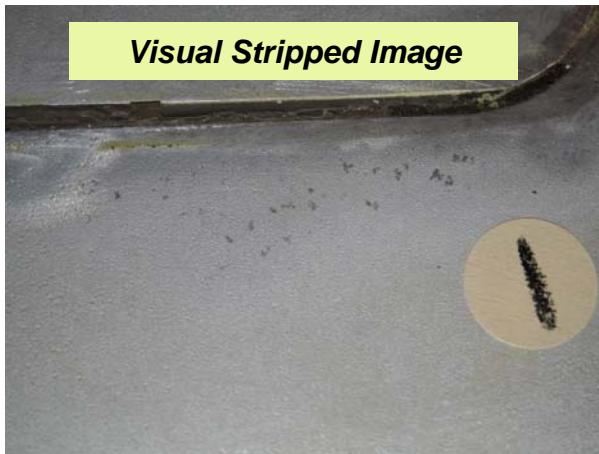
IR Flash Primer Image



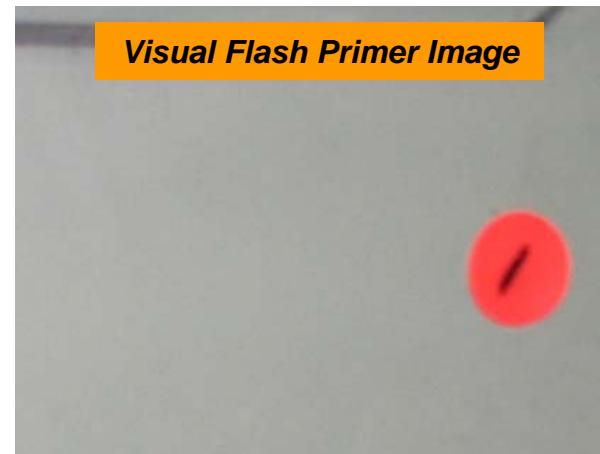
Visual Painted Image



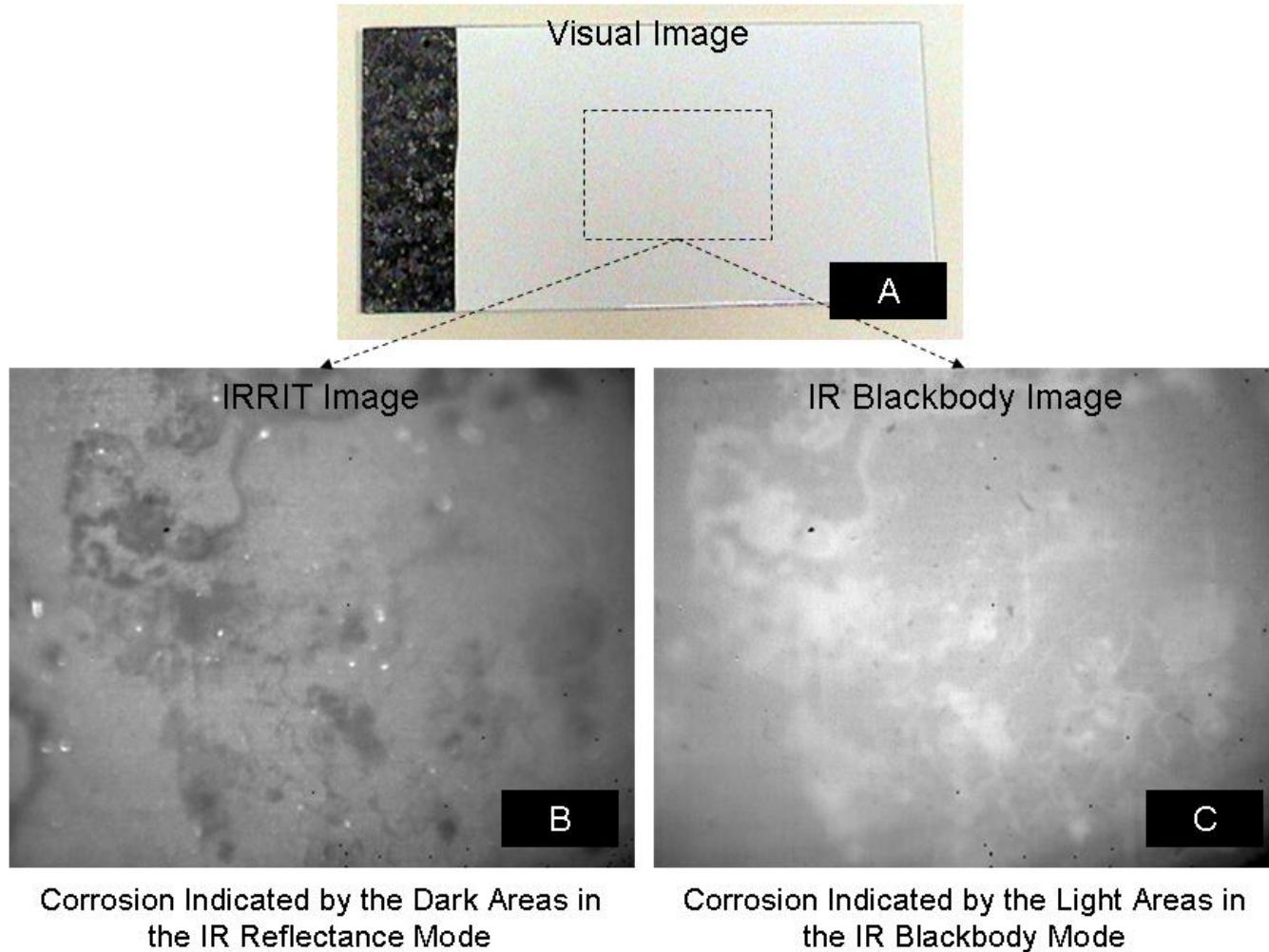
Visual Stripped Image



Visual Flash Primer Image

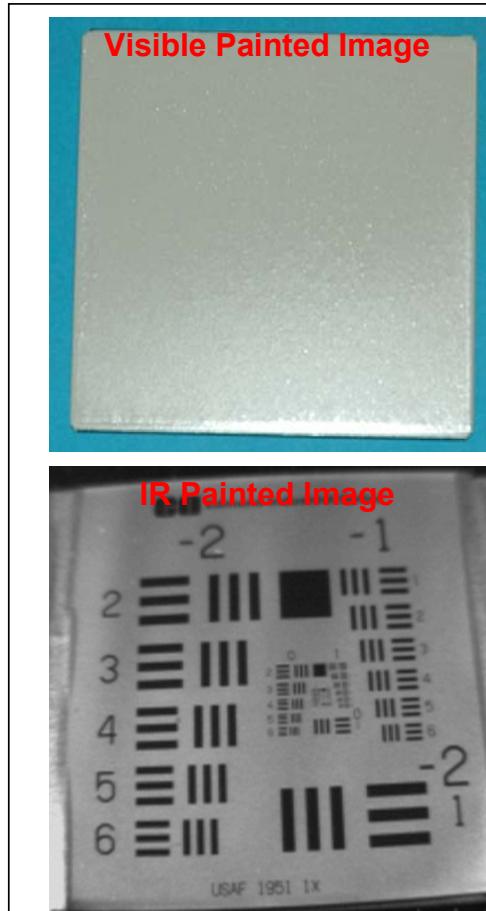


IRRIT Examples





IRRIT Examples



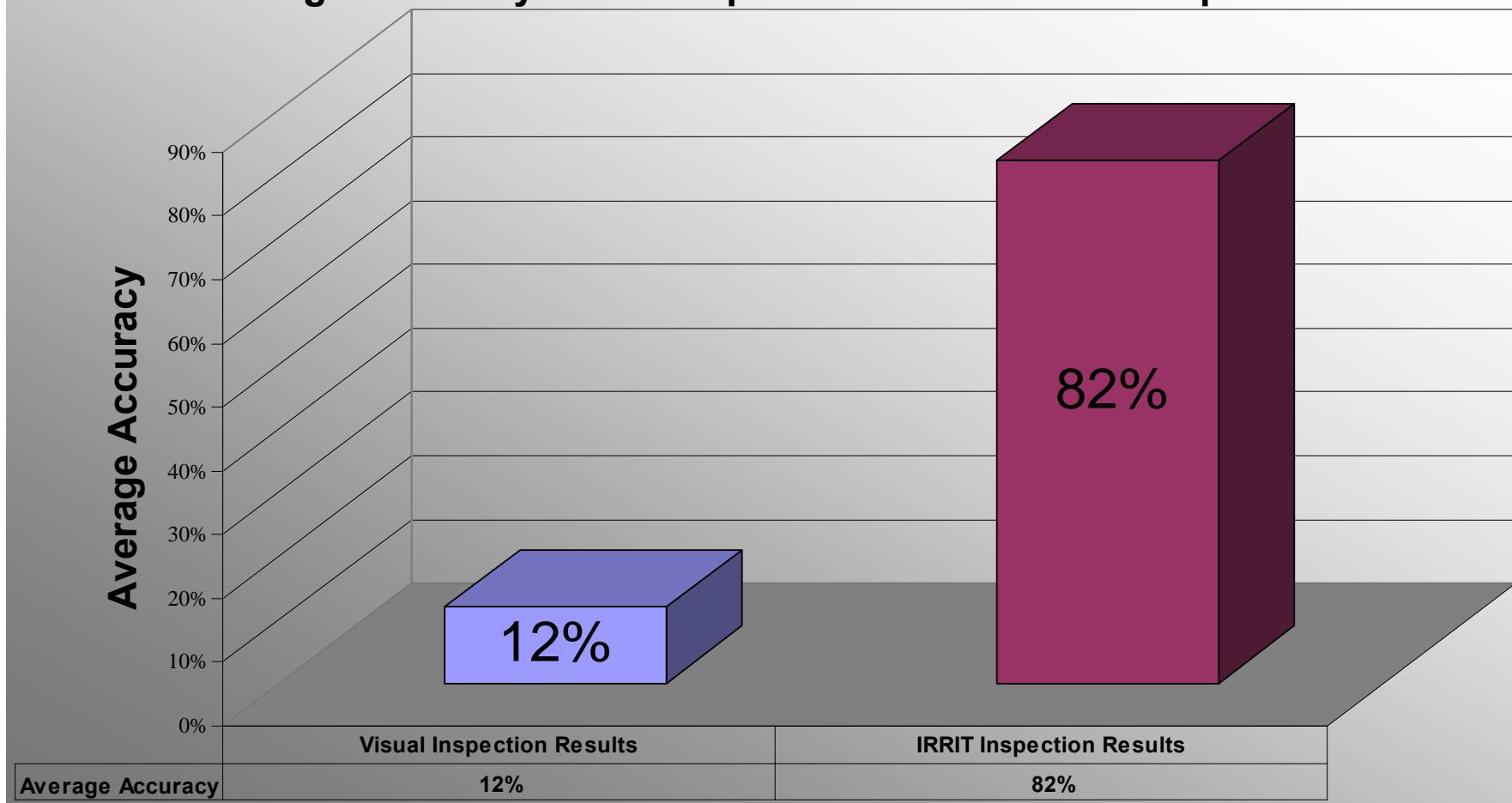
This standard was used in the laboratory to check the camera's resolution with and without various coatings applied to the surface. This standard was also checked prior and post all IRRIT inspections during the Dem/Val process. This standard ensures that the system is operating normally.

Note: This standard is painted with the same type of primer and topcoat that is on the P-3 aircraft.



Results – Weighted Average

Average Accuracy: IRRIT Inspection versus Visual Inspection





Navy P-3 Dem/Val Data Points Acquired (Raw Data)

| Navy P-3 Tail #912 | As Received (Primer + Topcoat) | | | | | | | |
|--------------------|--------------------------------|-----------------------------------|-------------------------------|--|----------------|------------|-------------------------|--------------------|
| | P-3 OML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | IR Video (hour:min:sec) | Date Data Acquired |
| | Wing | 26 Measurements (AVG = 2.44 mils) | 5 Measurements (AVG = 69.1°F) | 4 Measurements (AVG = 70.6°F) | 375 Images | 201 Images | 02:29:09 | 2/7/2006 |
| | Fuselage | 24 Measurements (AVG = 3.07 mils) | 3 Measurements (AVG = 70.1°F) | 4 Measurements (AVG = 71.9°F) | | | | 2/7/2006 |
| | Post Chemical Stripping | | | | | | | |
| | P-3 OML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | IR Video (hour:min:sec) | Date Data Acquired |
| | Wing | Not Required | 2 Measurements (AVG = 64.5°F) | 2 Measurements (AVG = 66.8°F) | 173 Images | 101 Images | 01:22:51 | 2/10/2006 |
| | Fuselage | Not Required | 1 Measurement (AVG = 71.8°F) | 4 Measurements (AVG = 78°F) | | | | 2/10/2006 |
| | Flash Primer | | | | | | | |
| | P-3 OML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | IR Video (hour:min:sec) | Date Data Acquired |
| | Wing | 26 Measurements (AVG = 0.79 mils) | 3 Measurements (AVG = 80.5°F) | 2 Measurements (AVG = 81.9°F) | 60 Images | 48 Images | NA | 5/8/2006 |
| | Fuselage | 9 Measurements (AVG = 0.54 mils) | 2 Measurements (AVG = 85.2°F) | 1 Measurement (AVG = 84.9°F) | | | | 5/8/2006 |



Navy P-3 Dem/Val Data Points Acquired (Raw Data)

| Navy P-3 Tail #772 | As Received (Primer + Topcoat) | | | | | | | | |
|--------------------|--------------------------------|---|--------------------------------|--|----------------|------------|-------------------------|--------------------|--|
| | P-3 OML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | IR Video (hour:min:sec) | Date Data Acquired | |
| | Wing | 15 Measurements (AVG = 3.59 mils) | 2 Measurements (AVG = 80.1°F) | 2 Measurements (AVG = 79.95°F) | 136 Images | 100 Images | 00:50:17 | 5/6/2006 | |
| | Fuselage | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) | | | | | | | |
| | Post Chemical Stripping | | | | | | | | |
| | P-3 OML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | IR Video (hour:min:sec) | Date Data Acquired | |
| | Wing | Not Required | 2 Measurements (AVG = 78.55°F) | 2 Measurements (AVG = 78.7°F) | 125 Images | 102 Images | NA | 5/10/2006 | |
| | Fuselage | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) | | | | | | | |
| | Flash Primer | | | | | | | | |
| | P-3 OML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | IR Video (hour:min:sec) | Date Data Acquired | |
| | Wing | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) | | | | | | | |
| | Fuselage | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) | | | | | | | |



Navy P-3 OML Real-Time Results vs Post-Processing Results

| Navy P-3 Tail #912 | Real-Time Results (P-3 OML Wing Section) | | | | |
|--------------------|--|--|-----------------|--------|------------------------|
| | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Actual Corrosion Sites |
| | Visual Inspection Results | 10 | 1 | 163 | 172 |
| | IRRIT Inspection Results | 128 | 0 | 44 | 172 |
| | Post-Processing Results (P-3 OML Wing Section) | | | | |
| | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Actual Corrosion Sites |
| | Visual Inspection Results | <i>Visual inspection does not allow for post-processing results.</i> | | | |
| | IRRIT Inspection Results | 135 | 0 | 37 | 172 |
| | Real-Time Results (P-3 OML Fuselage Section) | | | | |
| | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Actual Corrosion Sites |
| | Visual Inspection Results | 5 | 0 | 66 | 71 |
| | IRRIT Inspection Results | 55 | 0 | 16 | 71 |
| | Post-Processing Results (P-3 OML Fuselage Section) | | | | |
| | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Actual Corrosion Sites |
| | Visual Inspection Results | <i>Visual inspection does not allow for post-processing results.</i> | | | |
| | IRRIT Inspection Results | 57 | 0 | 14 | 71 |
| | 80% | | | | |



Navy P-3 OML Real-Time Results vs Post-Processing Results

| Navy P-3 Tail #772 | Real-Time Results (P-3 OML Wing Section) | | | | |
|---------------------------|--|------------------------------|-----------------|--------|------------------------|
| | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Actual Corrosion Sites |
| | Visual Inspection Results | 27 | 2 | 74 | 99 |
| | IRRIT Inspection Results | 75 | 0 | 24 | 99 |
| | Post-Processing Results (P-3 OML Wing Section) | | | | |
| | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Actual Corrosion Sites |
| Visual Inspection Results | <i>Visual inspection does not allow for post-processing results.</i> | | | | |
| IRRIT Inspection Results | 85 | 0 | 10 | 99 | 86% |



Navy P-3 Dem/Val IRRIT Scan Rates

| Navy P-3 Tail #912 | As Received (Primer + Topcoat) | |
|--------------------|--------------------------------|--|
| | P-3 OML Location | Scan Rate |
| | Wing | 64 ft ² /hour |
| | Fuselage | 73 ft ² /hour |
| | Post Chemical Stripping | |
| | P-3 OML Location | Scan Rate |
| | Wing | 150 ft ² /hour |
| | Fuselage | 207 ft ² /hour |
| | Flash Primer | |
| | P-3 OML Location | Scan Rate |
| Navy P-3 Tail #772 | Wing | 150 ft ² /hour |
| | Fuselage | Scan Rate Not Recorded |
| | As Received (Primer + Topcoat) | |
| | P-3 OML Location | Scan Rate |
| | Wing | 120 ft ² /hour |
| | Fuselage | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) |
| | Post Chemical Stripping | |
| | P-3 OML Location | Scan Rate |
| | Wing | Scan Rate Not Recorded |
| | Fuselage | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) |
| Flash Primer | | |
| P-3 OML Location | | Scan Rate |
| | Wing | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) |
| | Fuselage | NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations) |



USAF KC-135 Dem/Val Data Points Acquired (Raw Data)

| KC-135 #1 | Primer | | | | | | |
|---------------------------------------|----------------------------------|---|-------------------------------|--|----------------|------------|--------------------|
| | KC-135 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | Date Data Acquired |
| Bulkheads | 6 Measurements (AVG = 0.95 mils) | 0 Measurements (AVG = N/A) | 2 Measurements (AVG = 71.5°F) | 19 Images | 31 Images | 10/23/2006 | |
| Post Selected Spot Chemical Stripping | | | | | | | |
| KC-135 #2 | KC-135 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | Date Data Acquired |
| | Bulkheads | Not Required | 0 Measurements (AVG = N/A) | 0 Measurements (AVG = N/A) | 22 Images | 9 Images | 10/24/2006 |
| Primer | | | | | | | |
| KC-135 #3 | KC-135 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | Date Data Acquired |
| | Cargo Door | 11 Measurements (AVG = 1.31 mils) | 4 Measurements (AVG = 75.2°F) | 5 Measurements (AVG = 75.9°F) | 10 Images | 5 Images | 10/25/2006 |
| Primer | | | | | | | |
| KC-135 #3 | KC-135 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos | Date Data Acquired |
| | Port Wing Spar | NO MEASUREMENTS TAKEN – Purpose of IRRIT inspection was to show capability of the system in tight spaces. | | | | | 10/26/2006 |



USAF B-52 Dem/Val Data Points Acquired (Raw Data)

| Primer + Topcoat | | | | | | |
|---------------------------------------|-------------------|----------------------------------|------------------------------|--|----------------|-----------|
| B-52 #1 | B-52 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos |
| | Longerons | 6 Measurements (AVG = 1.57 mils) | 1 Measurement (AVG = 67°F) | 3 Measurements (AVG = 67.1°F) | 21 Images | 17 Images |
| Post Selected Spot Chemical Stripping | | | | | | |
| B-52 #1 | B-52 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos |
| | Longerons | Not Required | 0 Measurements (AVG = N/A) | 0 Measurements (AVG = N/A) | 10 Images | 21 Images |
| Primer + Topcoat | | | | | | |
| B-52 #2 | B-52 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos |
| | Longerons | 7 Measurements (AVG = 3.39 mils) | 1 Measurement (AVG = 70°F) | 4 Measurements (AVG = 71°F) | 11 Images | 10 Images |
| Post Selected Spot Chemical Stripping | | | | | | |
| B-52 #2 | B-52 IML Location | Paint Thickness Measurements | Air Temperature Measurements | Aircraft Skin Temperature Measurements | Visible Photos | IR Photos |
| | Longerons | Not Required | 0 Measurements (AVG = N/A) | 0 Measurements (AVG = N/A) | 10 Images | 12 Images |



USAF KC-135 IML Real-Time Results vs Post-Processing Results

| KC-135 #1 | | Real-Time Results (KC-135 IML Bulkhead) | | | | | |
|---|--|---|--|-----------------|--------|---------------------------|------------|
| | | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Confirmed Corrosion Sites | % Accuracy |
| Visual Inspection Results | | <i>No visual corrosion sites confirmed.</i> | | | | | |
| IRRIT Inspection Results | | 4 | 2 | * | 2 | ** | |
| KC-135 #2 | | Real-Time Results (KC-135 IML Cargo Door) | | | | | |
| | | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Confirmed Corrosion Sites | % Accuracy |
| Visual Inspection Results | | <i>No visual corrosion sites confirmed.</i> | | | | | |
| IRRIT Inspection Results | | 1 | <i>Unknown – No selective spot stripping occurred.</i> | | | | |
| KC-135 #3 | | Real-Time Results (KC-135 IML Port Wing Spar) | | | | | |
| | | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Confirmed Corrosion Sites | % Accuracy |
| | | Visual Inspection Results | <i>NO MEASUREMENTS TAKEN – Purpose of IRRIT inspection was to show capability of the system in tight spaces.</i> | | | | |
| IRRIT Inspection Results | | <i>Notes:</i> | | | | | |
| * = Due to the fact that selective spot stripping occurred (only for locations that were identified by the IRRIT as having corrosion beneath the coating), it is impossible to know if any other corrosion locations were missed. | | | | | | | |
| ** = Cannot determine accuracy solely based on spot stripping, because it is unknown whether or not corrosion was missed in areas that were not stripped. | | | | | | | |
| *** = Corrosion may have been removed by stripping process, mechanical abrasion may have occurred. | | | | | | | |



USAF B-52 IML Real-Time Results vs Post-Processing Results

| | | Real-Time Results (B-52 IML Longerons) | | | | | | |
|---|--|--|---|-----------------|--------|---------------------------|------------|--|
| | | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Confirmed Corrosion Sites | % Accuracy | |
| B-52 #1 | | Visual Inspection Results | <i>No visual corrosion sites confirmed.</i> | | | | | |
| | | IRRIT Inspection Results | 8 | 1*** | * | 7 | ** | |
| B-52 #2 | | Real-Time Results (B-52 IML Longerons) | | | | | | |
| | | Inspection Technique | Suspected Areas of Corrosion | False Positives | Misses | Confirmed Corrosion Sites | % Accuracy | |
| Notes: | | Visual Inspection Results | <i>No visual corrosion sites confirmed.</i> | | | | | |
| | | IRRIT Inspection Results | 2 | 1*** | * | 1 | ** | |
| * = Due to the fact that selective spot stripping occurred (only for locations that were identified by the IRRIT as having corrosion beneath the coating), it is impossible to know if any other corrosion locations were missed. | | | | | | | | |
| ** = Cannot determine accuracy solely based on spot stripping, because it is unknown whether or not corrosion was missed in areas that were not stripped. | | | | | | | | |
| *** = Corrosion may have been removed by stripping process, mechanical abrasion may have occurred. | | | | | | | | |

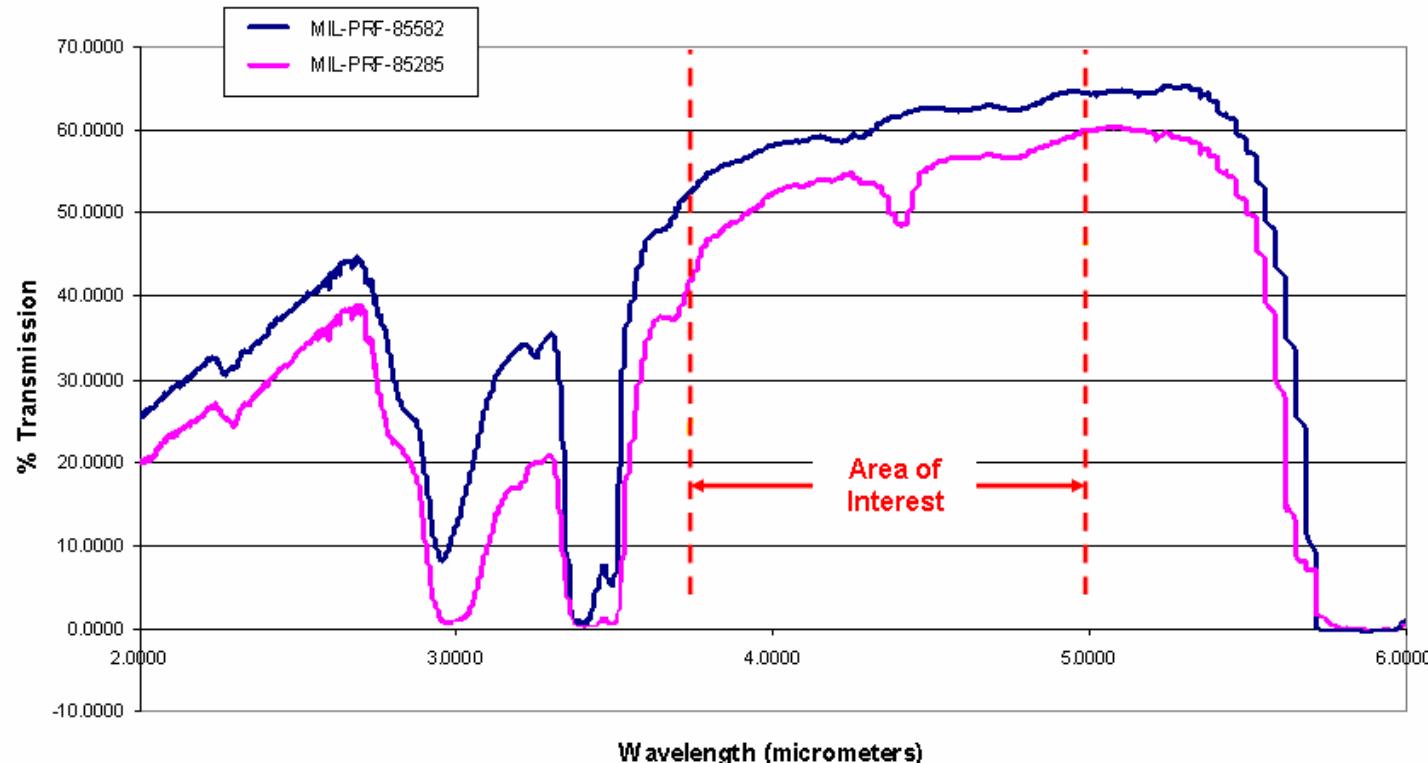


USAF KC-135 and B-52 Dem/Val IRRIT Scan Rates

| KC-135 #1 | | Primer |
|---------------------|--|---------------------------|
| KC-135 IML Location | | Scan Rate |
| Bulkheads | | 133 ft ² /hour |
| KC-135 #2 | | Primer |
| KC-135 IML Location | | Scan Rate |
| Cargo Door | | 150 ft ² /hour |
| KC-135 #3 | | Primer |
| KC-135 IML Location | | Scan Rate |
| Port Wing Spar | <i>NO MEASUREMENTS TAKEN – Purpose of IRRIT inspection was to demonstrate capability of the system in areas of limited access.</i> | |
| B-52 #1 | | Primer + Topcoat |
| B-52 IML Location | | Scan Rate |
| Longerons | | 108 ft ² /hour |
| B-52 #2 | | Primer + Topcoat |
| B-52 IML Location | | Scan Rate |
| Longerons | | 135 ft ² /hour |

IRRIT Examples

Optimal Wavelength Transmission Band

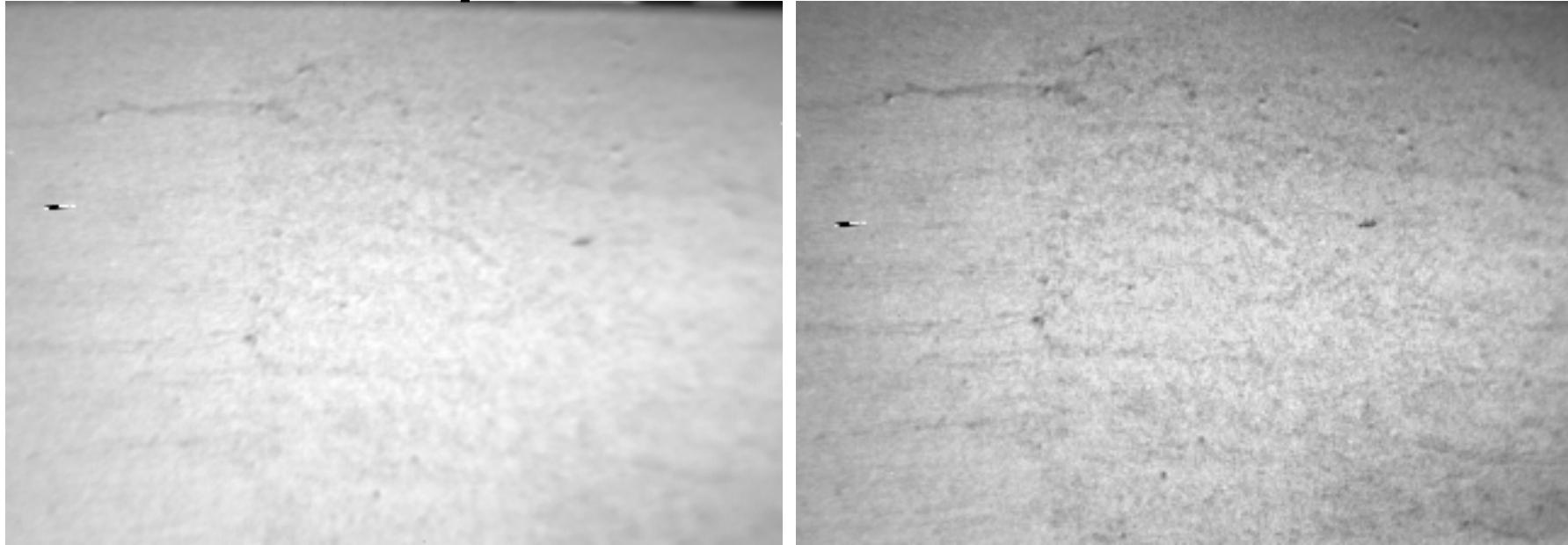


Note: Coatings are standard mil-spec thicknesses.



IRRIT Examples

Optimized Filter Results



3-5 μm : STANDARD FILTER

3.75-5 μm : OPTIMIZED FILTER

*****Received new Merlin IR camera with internal 3.75-5 micron filter.***